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SOIL CONSERVATION SERVICE-RESEARCH
WASHINGTON 25, D.C.

In Cooperation with the
Nebraska and Kansas Agricultural Experiment Stations

RATES OF RUNOFF FOR THE DESIGN OF CONSERVATION STRUCTURES IN THE CENTRAL GREAT PLAINS OF NEBRASKA AND KANSAS

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Division of Drainage and Water Control
Soil Conservation Service

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FOREWORD

This publication is one of a series containing information for use where peak rates of runoff are required for the design of hydrologic structures. Such factual information is needed for the economical design of spillways, diversions, culverts, terrace outlets, and other structures.

The design values, recommended in this report, are based primarily on an analysis of the hydrologic data collected by the Central Great Plains Experimental Watershed in cooperation with the Nebraska and Kansas Agricultural Experiment Stations. United States Weather Bureau records of precipitation and United States Geological Survey published and unpublished records of stream flow were also utilized in the analysis.

It is recognized that an 8-year record of surface runoff from small agricultural areas is insufficient data upon which to base conclusive recommendations. It was felt, however, that the need for information on peak rates of flow that might be expected from such areas justified the immediate publication of this report. Values presented in the report must be considered as tentative, and subject to revision as additional data become available.

M. L. Nichols
Chief of Research

ACKNOWLEDGMENTS

Establishment of the runoff studies and collection of the data which form the basis of this report involved the work of the author and other members of the Soil Conservation Service, both Research and Operations personnel. Among those who contributed to the success of the project were: I. W. Bauer, R. R. Drake, F. L. Duley, L. L. Kelly, H. R. Leach, C. E. Ramser, and J. C. Russel.

The studies were carried out under the supervision of Lewis A. Jones, chief, Division of Drainage and Water Control, Soil Conservation Service, Research, and in cooperation with the Nebraska Agricultural Experiment Station.

In determining the area of application and the form in which the data are presented the author was fortunate to have had the advice of Operations technicians of the regional and State offices of the Soil Conservation Service.

The author is indebted to the technical staff of the Division of Drainage and Water Control for their advice and assistance, and especially to W. D. Potter, under whose immediate direction the report was made, for his suggestions and technique for analysis of the data.

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PART I

Introduction

Early settlers in the Great Plains were interested in rainfall. This is evident from the long rainfall records, extending over seven decades. They also realized that the water in rivers was a great natural resource that could be used for irrigation, navigation, and power. Consequently, gaging stations were established to measure the stream discharge of some of the larger rivers, and today United States Geological Survey records on several of the more important rivers extend over half a century.

The measurements made by the United States Geological Survey were on streams draining large basins 500 square miles or more in area. In contrast to these measurements from large watersheds were the plot studies made by the erosion experiment stations and the State experiment stations on plots ranging from part of an acre to 2 acres in size. Between these two extremes little or no data on runoff from agricultural watersheds were available prior to 1933.

Soon after the formation of the Soil Erosion Service (now the Soil Conservation Service) in 1933, it was realized that information on runoff from small agricultural areas was essential to the safe and economical design of conservation structures and to the development of effective conservation measures. Accordingly, in 1935, a general working plan for runoff studies was prepared. This was followed by the selection of three experimental watersheds located at Coshocton, Ohio; Waco, Tex.; and Hastings, Nebr., where extensive hydrologic studies are now being conducted. Studies at the Central Great Plains Experimental Watershed, established in 1938 near Hastings, Nebr., are primarily the basis for this report. The findings are generally applicable to parts of Kansas and Nebraska shown in figure 1, page 2.

Description of the Central Great Plains Experimental Watershed

An area known locally as the Beaver Creek watershed, about 25 miles south of Hastings, Nebr., in the Republican River basin, was selected for the hydrological studies. The area is considered to be representative of the loessial region of the Central Great Plains and lies in latitude 40°14' N. and longitude 98°22' W.; elevations range from 1,800 to 2,000 feet above mean sea level (fig. 2, p. 3).

The stream system consists of two forks which unite a short distance below the project area. These two forks and their many small feeder drains have split the area in long tongues of gently rolling uplands. Land of less than 5 percent slope occurs on 47 percent of the area, and land steeper than 12 percent slope occurs on only 6 percent of the area. The drainage pattern of all the watersheds is fairly well defined.

The parent material of all the soils of the watershed, except the Nuckolls soils, is Peorian loess ranging up to 30 feet deep. Beneath the Peorian loess, or exposed in the Nuckolls soils, is the loessial phase of the Loveland formation, which ranges up to 90 feet deep or more. The wide range in depth of the two loessial deposits is due to the

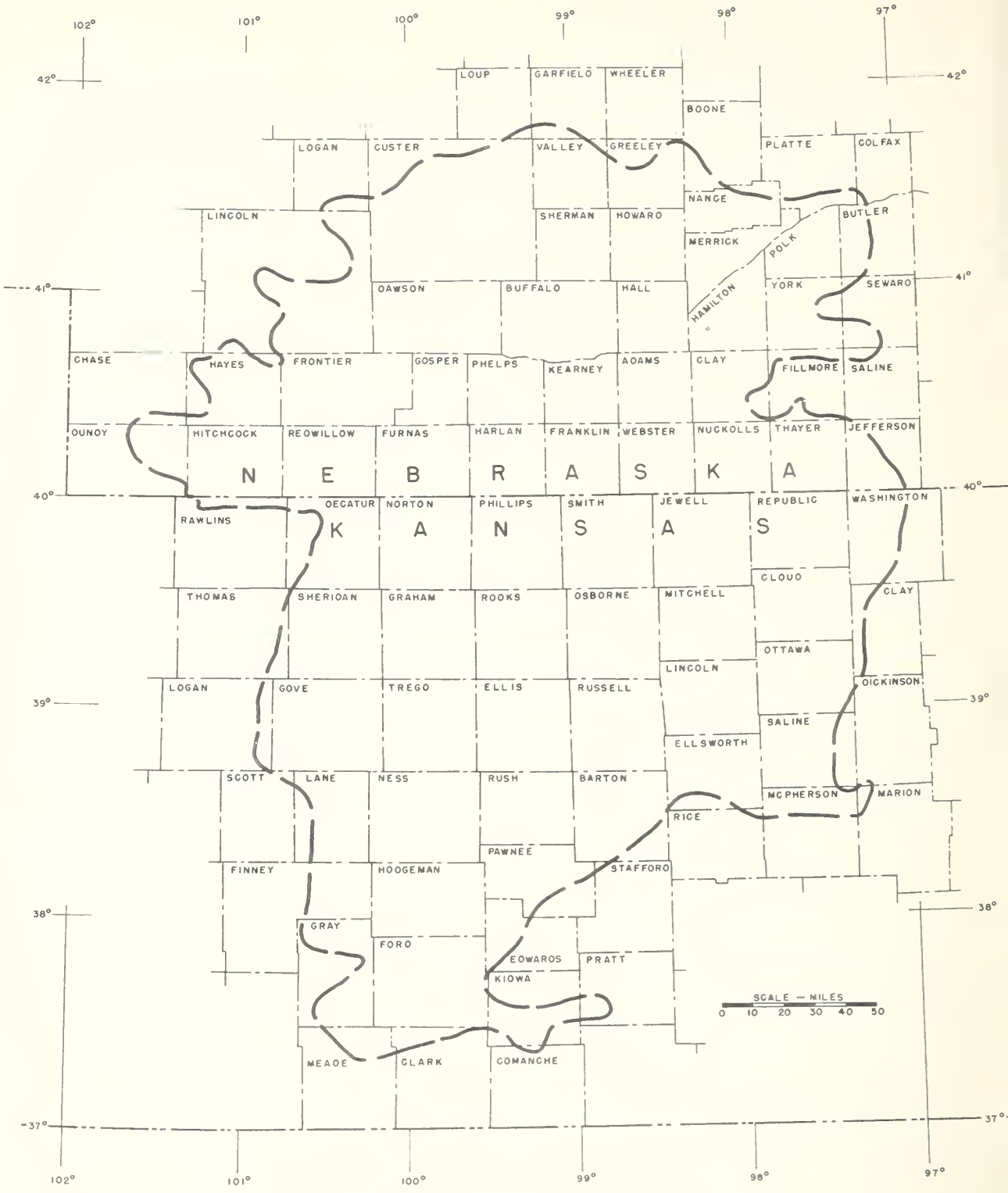
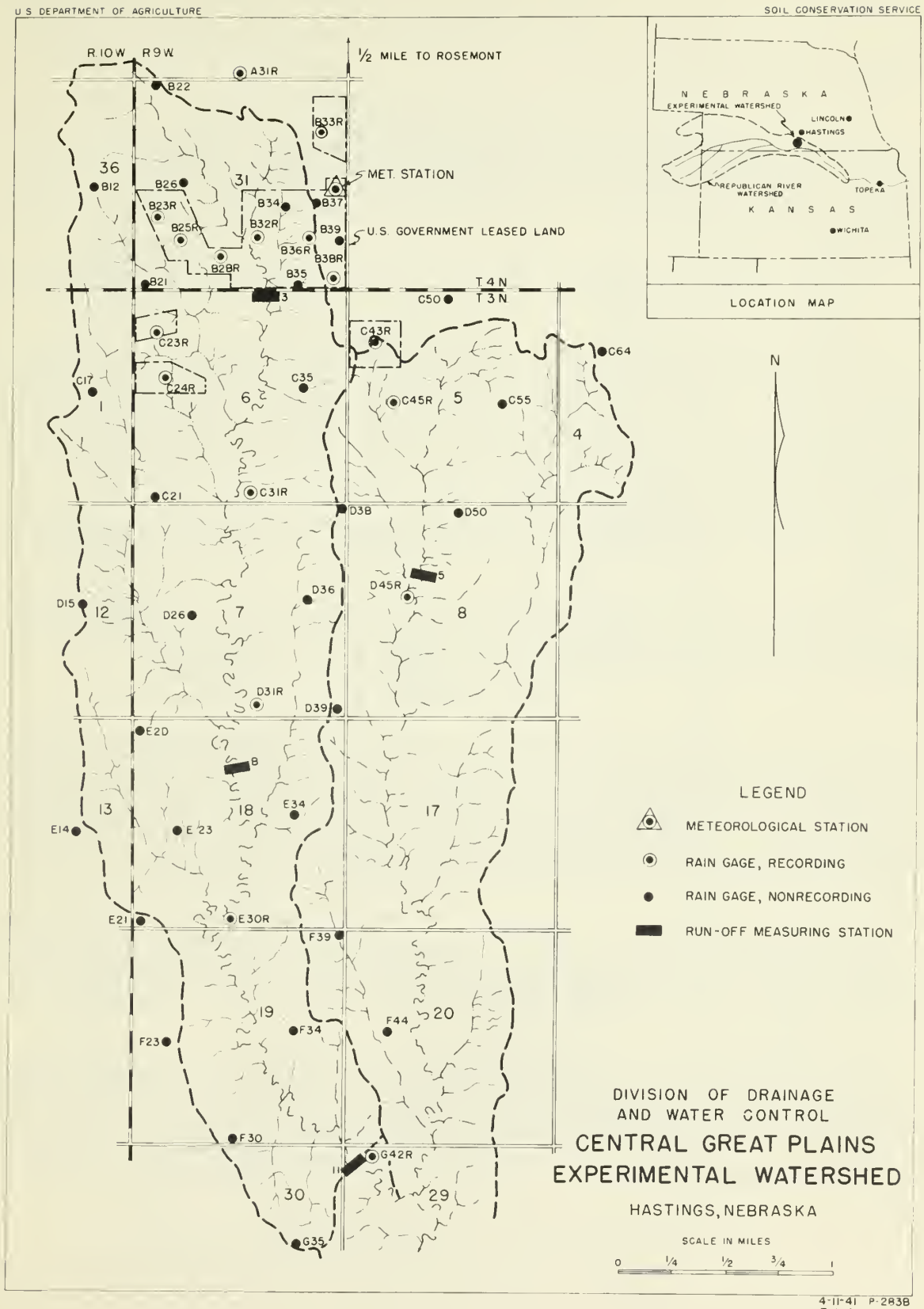


Figure 1.—Area of application.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SOIL CONSERVATION SERVICE
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R.9W.
½ MILE TO ROSEMONT
MET. STATION
U.S. GOVERNMENT LEASED LAND
T.4N.
T.3N.
NEBRASKA
EXPERIMENTAL WATERSHED
LINCOLN
HASTINGS
REPUBLICAN RIVER WATERSHED
TOPEKA
KANSAS
WICHITA
LOCATION MAP
N
LEGEND
METEOROLOGICAL STATION
RAIN GAGE, RECORDING
RAIN GAGE, NONRECORDING
RUN-OFF MEASURING STATION
DIVISION OF DRAINAGE AND WATER CONTROL
CENTRAL GREAT PLAINS EXPERIMENTAL WATERSHED
HASTINGS, NEBRASKA
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Figure 2

irregularities of the present terrain, but depth of the combined deposits is probably never less than 20 feet. Most of the soils have deep friable topsoils, usually with a silt loam texture. The percentage of each predominant soil type is: Hastings silt loam, 58; Holdrege silt loam, 10; Colby silt loam, 7; and Judson silt loam, 6. The remaining area is made up of other closely related soil types.

Observations indicate that on similar topography these soils vary little in fertility and productivity, and limited data show no difference in the rates of infiltration of the different soils.[1/] Protection of the soil surface by grasses, growing crops, or mulches will maintain rather high infiltration rates, but when this protection is lacking, a rain of fairly high intensity will quickly puddle the surface layers of soil, reduce the infiltration rate, and increase the runoff.[2/]

The water table lies at a depth of 40 to 120 feet, and no accretion to stream flow comes from ground water.

The climate of this area is characterized by cold, relatively dry winters, hot summers, fairly heavy summer rainfall, relatively low humidity, and a moderately long frost-free growing season. The mean annual temperature at Hastings for the 51-year period, 1895-1946, is 51.0° F., and the mean annual precipitation, 24.47 inches. About 74 percent of the precipitation occurs in the 6 months from April through September. High intensities of the summer rains and hot dry winds during the dry periods between the storms constitute a serious agricultural problem. Ordinarily, because the winter winds blow snow from the smooth fields of winter wheat and other fields with sparse cover, little snow moisture becomes available for crop growth. Consequently, yields of winter wheat are dependent upon moisture that has accumulated in the soil between the time of harvest and the beginning of winter.

About 20 percent of the area in the Beaver Creek watershed is in permanent native-grass pasture, 4 percent is in permanent native-grass meadow, 73 percent is under cultivation, and 3 percent is in miscellaneous uses, such as roads and farmsteads.

Experimental Set-up

The Central Great Plains Experimental Watershed is operating under five distinct working plans, which have been approved by the Director of the Nebraska State Agricultural Experiment Station and various Soil Conservation Service technicians interested in and responsible for the Soil Conservation Service research program. Data collected under working plan No. 1, "The Effect of Land Use and Soil Conservation Practices on Runoff from Small Watersheds," and working plan No. 3, "Characteristics of Flood Runoff from Agricultural Areas of Different Sizes," are the main sources for this publication.

Under working plan No. 1, 21 cultivated watersheds farmed under field conditions and 3 native-grass watersheds, each about 4 acres, were established in 1939-41 (fig. 3, p. 5). Runoff records from these natural watersheds have been both used singly and also, by combining the hydrographs where feasible, used to determine peak rates from approximately 4, 8, and 12 acres.

1/ UNITED STATES SOIL CONSERVATION SERVICE, HYDROLOGIC DIVISION. Hydrologic Data: Central Great Plains Experimental Watershed, Hastings, Nebraska, 1938-1940. U. S. Dept. Agr. Hydrol. Bul. 3, 148 pp., illus. 1942.

2/ DULEY, F. L., and KELLY, L. L. Surface Condition of Soil and Time of Application as Related to Intake of Water. U. S. Dept. Agr. Cir. 608, 30 pp., illus. 1941.

DIVISION OF DRAINAGE AND WATER CONTROL
SMALL WATERSHEDS
CENTRAL GREAT PLAINS EXPERIMENTAL WATERSHED

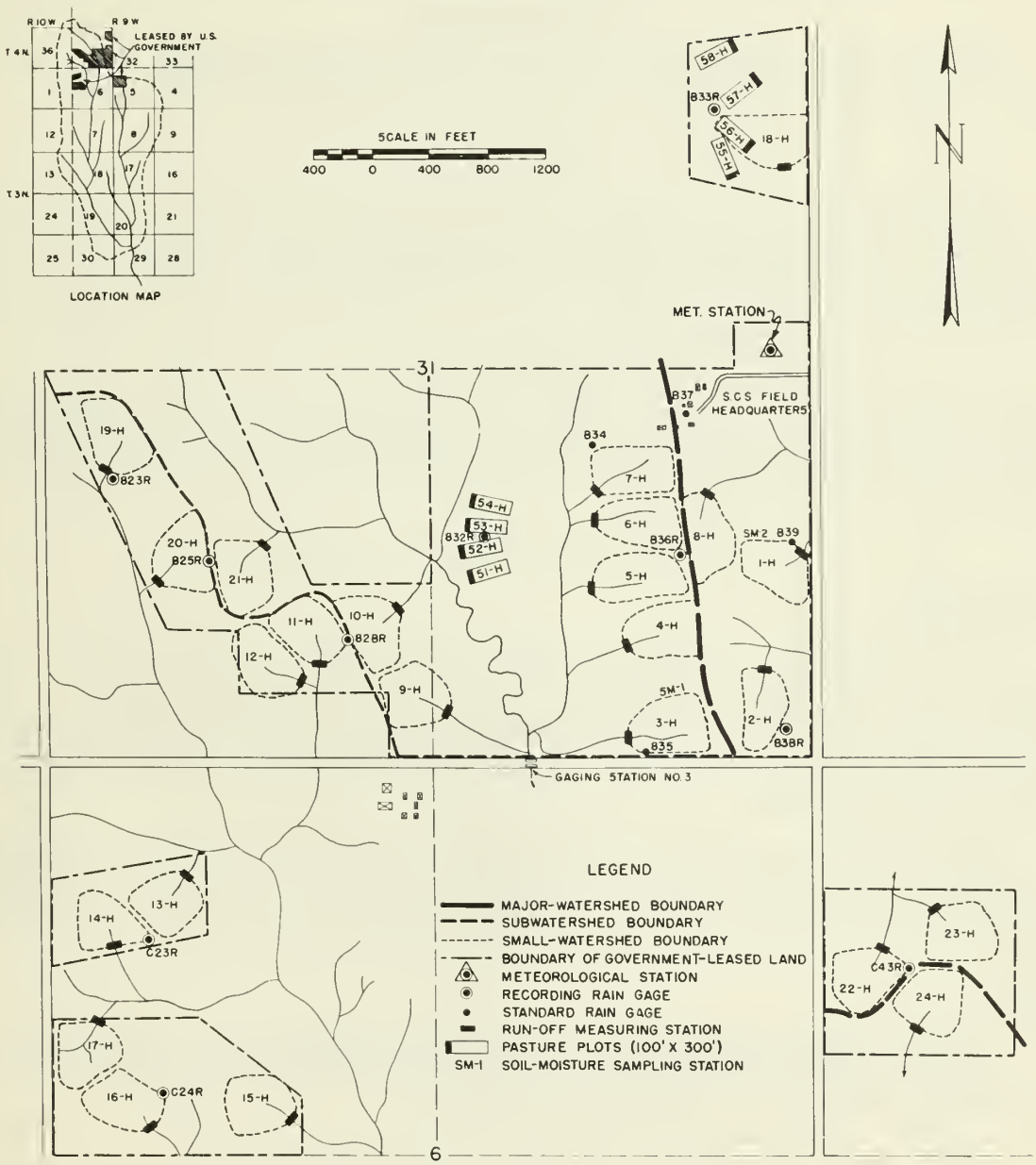

Figure 3 – Small watersheds of Central Great Plains Experimental Watershed, Hastings, Nebraska

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Under working plan No. 3, four gaging stations with areas ranging in size from 411 to 3,490 acres were established in 1938-39 (fig. 2, p. 3).

Accurate topographic, soils, and erosion maps have been made for each watershed. Vegetal cover and land-use surveys have been made periodically.

Physiographic Characteristics

The physiographic characteristics of each watershed are shown in table 1, page 7. See also the folded topographic map (fig. 7) in the envelope at the back of this publication.

Soil Characteristics

A detailed conservation survey was made in 1939 by Lloyd E. Mitchell, survey supervisor. The soil characteristics of the watersheds are summarized in table 2, page 8.

Land Use

Land-use surveys have been made each year on the various watersheds. The 24 small watersheds, each about 4 acres in size, are on land leased by the Government, and land use is controlled. A rotation of corn, oats, and wheat is followed on the 21 small watersheds that are under cultivation and the remaining 3 are kept in native grass. Land use on the 4 watersheds of 411 to 3,490 acres is not controlled. The percentage of land devoted to each crop over the period of record is listed in table 3, page 9.

The crop rotation generally used in this region is corn, oats, barley or fallow, and winter wheat. When the moisture conditions are favorable it is a common practice to ignore the rotation and plant the crop, either corn or wheat, that will produce the highest cash income. Corn and wheat acreages have been increased in the last few years with the rising prices for these commodities.

Instrumentation and Collection of Records

Precipitation

Rainfall intensities and amounts are measured by Fergusson recording rain and snow gages with a depth capacity of 9 inches and operating on chart scales of 1 inch equals 32 minutes and 1 inch equals 0.67 inch depth of rainfall. All recording rain gages are serviced by project personnel both periodically and after each rain. A typical rainfall station is shown in plate 1, page 10. These stations are located approximately 1 mile apart over the area, with additional stations in the leased area to provide more intensive information for the small watersheds.

Rainfall amounts are also measured by United States Weather Bureau 8-inch standard rain gages. These gages are read daily at 8:00 a. m. by local paid observers. These gages supplement the recording gages so as to provide a rain gage every half mile throughout the area.

Runoff

Two kinds of runoff measuring devices are in operation: (1) Those having flow-measuring devices that have been previously calibrated, and (2) those requiring field calibration by means of current-meter measurements of discharge.

TABLE 1.--*Physiographic characteristics of each watershed*

Watershed	Drainage area	Area in slope class of--					Average slope	Elevation (Mean sea level)		Length of principal water-course	Slope of principal water-course	Drainage density[1]	Form factor[2]	Meander factor[3]
		0-2 percent	2-5 percent	5-8 percent	8-12 percent	Over 12 percent		Lowest	Highest					
	acres	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*feet*	*feet*	*feet*	*percent*			
W-5	411	14	25	43	9	9	5.9	1,898	2,008	7,560	1.4	81.6	0.28	1.07
W-3	481	26	28	21	15	10	5.4	1,925	2,002	8,920	.86	80.3	.30	1.17
W-8	2,086	20	24	36	14	6	5.6	1,872	2,002	26,100	.50	55.9	.18	1.74
W-11	3,490	20	31	34	10	5	5.2	1,836	2,002	38,300	.43	72.3	.12	1.96
1-H	3.62	4	12	43	37	4	7.2	1,943	1,972	430	8.4	118	.81	1.00
2-H	3.40	8	38	25	19	10	6.7	1,944	1,973	600	4.8	176	.34	1.00
3-H	3.95	1	36	39	19	5	6.1	1,941	1,972	610	5.1	154	.51	1.00
4-H	3.84	1	41	39	15	4	6.2	1,947	1,979	510	6.3	132	.52	1.00
5-H	3.93	2	51	33	11	3	4.9	1,945	1,977	660	4.9	168	.41	1.00
6-H	4.16	6	63	21	9	1	4.4	1,947	1,973	600	4.3	144	.46	1.00
7-H	4.15	11	42	41	4	2	4.6	1,950	1,971	610	3.4	147	.47	1.00
8-H	3.93	16	74	10	0	0	3.0	1,963	1,979	620	3.8	158	.41	1.00
9-H	3.78	14	42	37	7	0	4.8	1,941	1,961	530	3.8	140	.54	1.00
10-H	3.98	15	60	35	0	0	3.9	1,942	1,962	390	5.1	98.0	.69	1.00
11-H	3.85	16	37	42	5	0	4.5	1,951	1,975	600	4.0	156	.53	1.00
12-H	3.66	4	41	30	23	2	5.8	1,950	1,979	500	5.8	137	.44	1.00
13-H	3.41	2	31	57	10	0	5.6	1,942	1,971	440	6.6	129	.70	1.00
14-H	3.35	0	41	46	13	0	5.4	1,954	1,979	475	5.3	142	.69	1.00
15-H	3.62	3	23	62	11	1	5.8	1,933	1,963	525	5.7	145	.58	1.00
16-H	3.57	2	61	32	4	1	4.6	1,949	1,975	460	5.7	129	.48	1.00
17-H	3.96	3	27	38	27	5	7.0	1,949	1,976	490	5.5	124	.69	1.00
18-H	3.74	4	37	52	6	1	4.9	1,944	1,974	525	5.7	140	.63	1.00
19-H	4.10	0	45	52	3	0	5.7	1,959	1,987	515	5.4	126	.61	1.00
20-H	4.05	0	45	37	11	7	6.1	1,945	1,971	420	6.2	104	.59	1.00
21-H	3.94	0	47	40	11	2	5.7	1,949	1,979	570	5.3	145	.57	1.00
22-H	3.99	8	69	23	0	0	3.8	1,959	1,977	505	3.2	126	.70	1.00
23-H	4.06	0	68	25	7	0	4.5	1,953	1,975	530	4.2	131	.59	1.00
24-H	4.21	0	58	24	14	4	5.0	1,953	1,971	475	3.8	113	.80	1.00

[1]Drainage density is the length of the waterway per acre and is determined by dividing the total length (ft.) of all drainageways, both main and tributary, by the area of the watershed (acres).

[2]Form factor is a dimensionless figure expressed as the ratio of width to length of watershed and is determined by dividing the area (sq. ft.) by the square of the length (ft.) of the watershed.

[3]Meander factor is a dimensionless figure expressed as the ratio of the length of the meandering channel divided by the length of the flood plain.

TABLE 2.--*Soil characteristics*

Watershed	Surface texture	Subsoil permeability	Erosion losses	Effective depth
W-5.....	Medium	Moderately slow	Moderate to severe	Deep
W-3.....	Medium	Moderately slow	Moderate to severe	Deep
W-8.....	Medium	Moderately slow	Moderate to severe	Deep
W-11.....	Medium	Moderately slow	Moderate to severe	Deep
1H.....	Medium	Moderately slow	Moderate	Deep
2H.....	Medium	Moderately slow	Moderate	Deep
3H.....	Moderately heavy	Slow	Moderate to moderately severe	Deep
4H.....	Medium	Moderately slow	Moderate	Deep
5H.....	Medium	Moderately slow	Moderate	Deep
6H.....	Medium	Moderately slow	Moderate	Deep
7H.....	Medium	Moderately slow	Moderate	Deep
8H.....	Medium	Moderately slow	Moderate	Deep
9H.....	Medium	Moderately slow	Moderate	Deep
10H.....	Medium	Moderately slow	Moderate	Deep
11H.....	Medium	Moderately slow	Moderate	Deep
12H.....	Moderately heavy	Slow	Moderate to moderately severe	Deep
13H.....	Moderately heavy to heavy	Very slow	Moderately severe to severe	Deep
14H.....	Moderately heavy	Slow	Moderate to moderately severe	Deep
15H.....	Moderately heavy to heavy	Very slow	Moderately severe to severe	Deep
16H.....	Moderately heavy to heavy	Very slow	Severe to moderately severe	Deep
17H.....	Moderately heavy	Slow	Moderate to moderately severe	Deep
18H.....	Medium	Moderately slow	Moderate	Deep
19H.....	Moderately heavy to heavy	Very slow	Moderately severe to severe	Deep
20H.....	Moderately heavy to heavy	Very slow	Moderately severe to severe	Deep
21H.....	Moderately heavy to heavy	Very slow	Moderately severe to severe	Deep
22H.....	Medium	Moderately slow	Moderate	Deep
23H.....	Moderately heavy	Slow	Moderate to moderately severe	Deep
24H.....	Moderately heavy to heavy	Very slow	Moderately severe to severe	Deep

TABLE 3.--*Average land use on the four large watersheds*

Land use	W–5	W–3	W–8	W–11
	Percent.	*Percent.*	*Percent.*	*Percent.*
Crops intertilled:				
Corn	33.7	31.7	30.5	28.4
Sorghum	5.2	3.6	4.9	5.2
Crops drilled or broadcast:				
Wheat	12.6	21.1	16.2	17.0
Oats	8.1	12.4	10.6	10.0
Barley	2.6	2.4	2.8	3.3
Rye	1.8	1.9	.9	1.3
Sorghum	1.1	2.3	3.2	3.1
Millet	.1	.6	.2	.4
Other:				
Meadow	10.4	1.7	4.8	3.4
Pasture	10.2	15.8	17.8	19.5
Alfalfa–Sweet Clover	.3	1.0	1.7	1.2
Fallow	8.2	2.4	3.1	3.6
Idle	2.3	0	.1	.1
Farmsteads	2.7	2.5	1.1	1.7
Roads	.7	.6	2.1	1.8

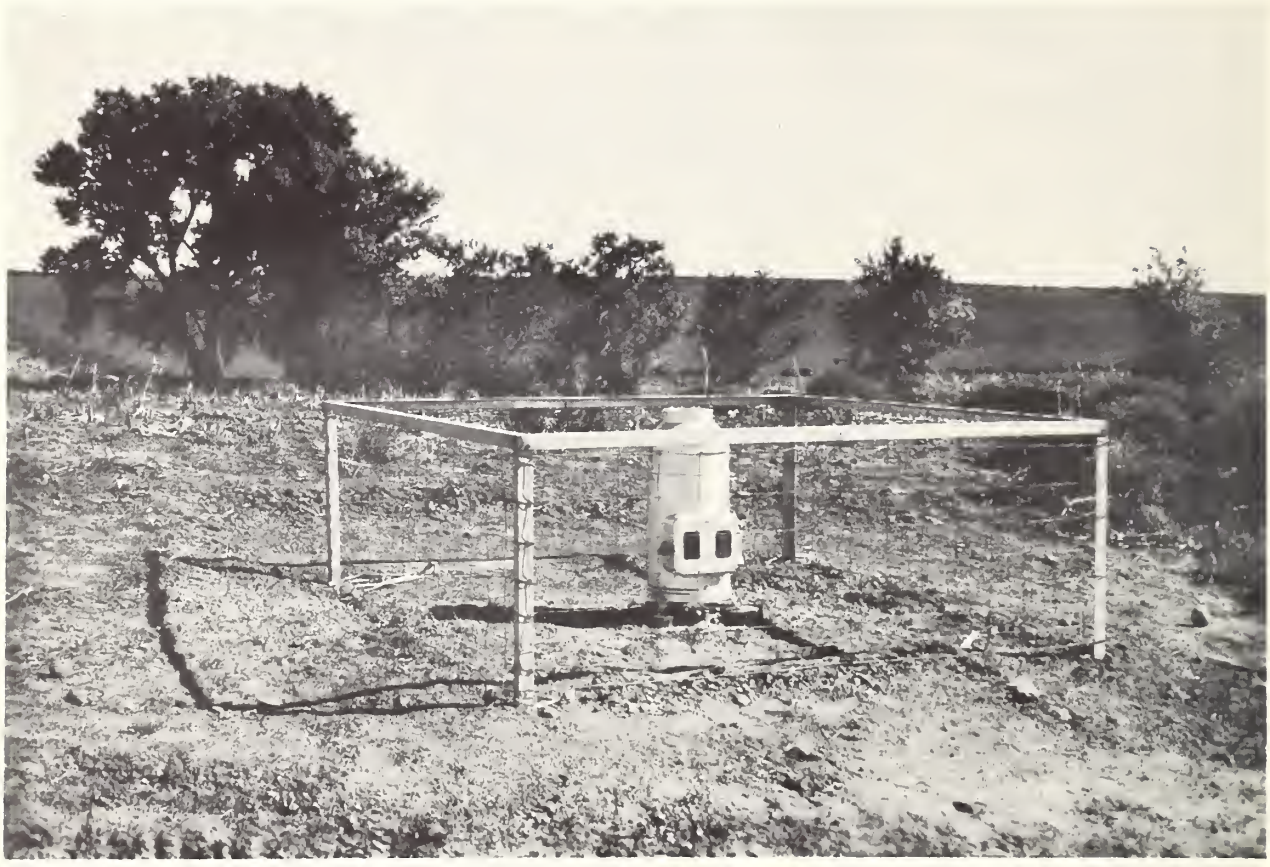


PLATE 1.--A typical installation of a Fergusson recording rain and snow gage.

The only precalibrated flume installed on this project was designed by the Soil Conservation Service to measure rates of flow up to 30 second-feet. A typical installation is shown in plate 2, page 12. It consists of vertical side walls cut back on a slope at the outlet so as to give a trapezoidal projection of the outlet. The H flume was calibrated in hydraulic laboratories by the Soil Conservation Service and was constructed in the field with all conditions as nearly identical as possible with those under which they were rated.

For the watersheds of 411 to 3,490 acres in size, a broad-crested V-notch control with 1-to-3 side slopes is used to control the stage-discharge relation for low flows, and the stabilized channel serves as a control for medium and high flows (pls. 3 and 4, pp. 13 and 14). Each of these stations is rated by current-meter measurements made in accordance with United States Geological Survey methods.

FW-1 water-stage recorders that operate on chart scales of 1 inch equals 25 minutes and 1 inch equals 0.20-foot stage are used on all runoff-measuring stations (pl. 5, p. 15).

Soil Moisture

The soil moisture (percent of dry-soil weight) is measured on the small 4-acre cultivated watersheds at the time of planting and again at harvest. Samples from the native-grass watersheds are taken in the spring and again in the fall. Samples are taken with sampling tubes at four sites on each watershed, selected to represent the area.

Other Meteorological Records

Records of temperature, humidity, evaporation, barometric pressure, wind movement, and sunshine are obtained at the central meteorological station (pl. 6, p. 16). Records of relative humidity and dew point are obtained by means of a sling psychrometer. Soil temperatures at 1 inch, 18 inches, and 36 inches are obtained by a triple record thermograph. Evaporation is measured in a United States Weather Bureau class A pan, a Colorado pan, and a Bureau of Plant Industry pan.

Records

The records of stage are first corrected for errors in gage height and time due to ordinary errors, such as datum shifts, intake stoppages, paper expansion and contraction, improper settings, and instrument irregularities. All of these, except datum shifts, are noted at each station by routine inspections. Annually or oftener, elevations of flumes, weirs, and recorders are checked by levels.

The corrected gage heights are transferred from the recorder charts to computation sheets on which are tabulated the time and stage for (1) each clock 5-, 10-, or 15-minute period; (2) each change in direction of the stage graph, and (3) each additional point to define the hydrograph and to compute the runoff amounts within allowable limits of error. Discharge tables, devised either from laboratory calibrations or from current-meter measurements, give the discharge in second-feet and inches per hour for each tabulated stage. The discharge for each tabulated time is averaged with that for the preceding time, and this average discharge for the time interval is converted to the amount of runoff in inches for the interval. The runoff amounts for each interval are then accumulated, giving the mass runoff that has passed the station up to any time.

PLATE 2.--A 3-foot H flume and approach box.

PLATE 3.--Gaging station W-3: Looking upstream at the 1-to-3 broad-crested V-notch control, overflow section and submergence gage.

PLATE 4.--Gaging station W-3: Flow of approximately 95 cubic feet per second, June 20, 1939.

PLATE 5.--A runoff measuring station with a 2-foot H flume and FW-1 water-stage recorder.

PLATE 6.--The central meteorological station showing instrument shelter, anemometer, rain gages, and evaporation pans.

PART II

General Design Data

In using the design values presented in this report, the possibility of a change in land use from that existing at the time of planning to another that would result in higher peak runoff rates should not be overlooked. Land that is pasture or meadow today may be broken up and put under cultivation tomorrow. Such a change could occur in spite of an existing agreement on the part of the owner to farm the land in accordance with a definite conservation plan. Changes in ownership, in the economic relationships between products, or changes dictated by the national welfare many times result in a changed land use. A structure should be designed for the highest values of runoff that might occur during its expected economic life. For example, if a diversion is to be designed for land that is now in pasture but is capable of being cultivated, runoff from cultivated land rather than that from grassland should be considered. If, however, the pasture is steep, rough, and not arable, a ditch designed to carry the runoff from grassland would be sufficient.

Peak rates of runoff for cultivated, mixed cover, and grassland areas that may be expected once in 10 years and once in 25 years are given in table 4, page 18, and shown graphically in figures 4 and 5, pages 19 and 20, for drainage areas ranging in size from 2 to 400 acres. Peak rates that may be expected 1 year in 50 may be obtained by multiplying the 1 year in 25 values by 1.17.

The term expectancy as used in this report refers to averages over a long period of time. To say that a peak rate of runoff has an expectancy of 1 year in 25 does not mean that it occurs once every 25 years. It may be equaled or exceeded the day after or the year after the completion of a conservation structure. But over 100 years, for example, there would have been only 4 years during which the rate would have been equaled or exceeded, or an average of 1 year in 25.

Ordinarily, structures on drainage areas of less than 200 acres should not be designed for higher peak rates than those having expectancies of 1 year in 25 years. Where considerable damage would be caused or life would be endangered by the failure of a structure, however, designing for peak rates having expectancies of 1 year in 50 years or more are justified. In designing field structures such as diversions or terrace-outlet channels, it is probably sound economy to plan on repairing or replacing them once in 10 years, on the average, rather than on expending the additional money and labor required for a larger structure that would have to be repaired or replaced only once in 25 to 50 years.

One of the characteristics of the Central Great Plains is the meandering of the stream channels; that is, the twisting and turning of a channel within its own flood plain (pls. 7 and 8, pp. 21 and 22). This meandering usually begins when the drainage area reaches about 400 acres in size. Its effect is to reduce the peak rates of runoff, because of the additional channel storage and the increased time of concentration. The relationship between drainage area and peak rates of runoff for two conditions of meander is shown in figure 6, page 23, and the amount of meander for the various experimental areas is expressed by a meander factor in table 1, page 7. In using the curves in figure 6, it will be necessary to compute the meander factor for drainage areas greater than 400 acres. The upper curve applies when there is no meander (meander factor = 1.00), and the lower curve when the meander factor is equal to or greater than 1.75. When the meander factor is greater than 1.00 but less than 1.75, the difference between the upper and lower curve values should be prorated in accordance with the meander factors.

TABLE 4.--*Peak rates of runoff for the design of conservation structures in the Central Great Plains of Nebraska and Kansas for expectancies of 1 year in 10 years and of 1 year in 25 years*

IMPORTANT: This table is applicable only for conditions resembling the following:

Topsoil texture	Medium
Soil permeability	Moderately slow
Effective depth of soil	Deep
Slope	Not more than 20% of area above 8% slope

Expectancy of 1 year in 10 years				Expectancy of 1 year in 25 years[1]			
	Cover condition				Cover condition		
Drainage area (acres)	Cultivated land	Mixed 20-80[2]	Grassland	Drainage area (acres)	Cultivated land	Mixed 20-80[2]	Grassland
	c.f.s.	*c.f.s.*	*c.f.s.*		*c.f.s.*	*c.f.s.*	*c.f.s.*
2	16.6	14.3	10.3	2	20.8	17.9	12.9
4	26.0	22.4	16.0	4	32.5	28.0	20.0
6	33.8	29.1	20.8	6	42.2	36.4	26.0
8	40.7	35.0	25.1	8	50.8	43.8	31.4
10	47.0	40.4	28.9	10	58.8	50.5	36.1
12	52.8	45.5	32.6	12	66.0	56.8	40.8
14	58.4	50.2	35.9	14	73.0	62.8	44.9
16	63.6	54.7	39.2	16	79.5	68.4	49.0
18	68.6	58.9	42.3	18	85.8	73.6	52.9
20	73.5	63.1	45.2	20	91.9	78.9	56.5
25	84.8	73.1	52.3	25	106	91.4	65.4
30	95.5	82.1	58.8	30	119	103	73.5
35	107	90.6	64.9	35	134	113	81.1
40	115	98.7	70.8	40	144	123	88.5
45	124	107	76.4	45	155	134	95.5
50	133	114	81.7	50	166	143	102
60	149	129	91.9	60	186	161	115
70	165	142	102	70	206	178	128
80	180	155	111	80	225	194	139
90	194	167	120	90	243	209	150
100	208	179	128	100	260	224	160
110	221	190	136	110	276	238	170
120	234	201	144	120	293	251	180
130	246	212	152	130	308	265	190
140	258	222	159	140	323	278	199
150	270	232	166	150	338	290	208
160	281	242	173	160	351	303	216
170	293	252	180	170	366	315	225
180	304	261	187	180	380	326	234
190	314	270	194	190	393	338	243
200	325	279	200	200	406	349	250
210	335	288		210	419	360	
220	345	297		220	432	371	
230	355	305		230	444	382	
240	365	314		240	457	393	
250	375	322		250	469	403	
260	385	331		260	482	414	
270	394	339		270	493	424	
280	403	347		280	504	434	
290	412	354		290	516	443	
300	422	362		300	528	453	
310	431	370		310	539	463	
320	440	378		320	551	473	
330	448	385		330	560	482	
340	457	393		340	572	492	
350	466	400		350	583	500	
360	474	407		360	593	509	
370	483	415		370	604	519	
380	491	422		380	614	528	
390	499	429		390	624	537	
400	508	436		400	636	546	

[1]For peak rates having an expectancy of 1 year in 50 years, multiply these values by 1.17.

[2]'Mixed cover, 20-80,' refers to watersheds containing approximately 20 percent grassland and 80 percent cultivated land.

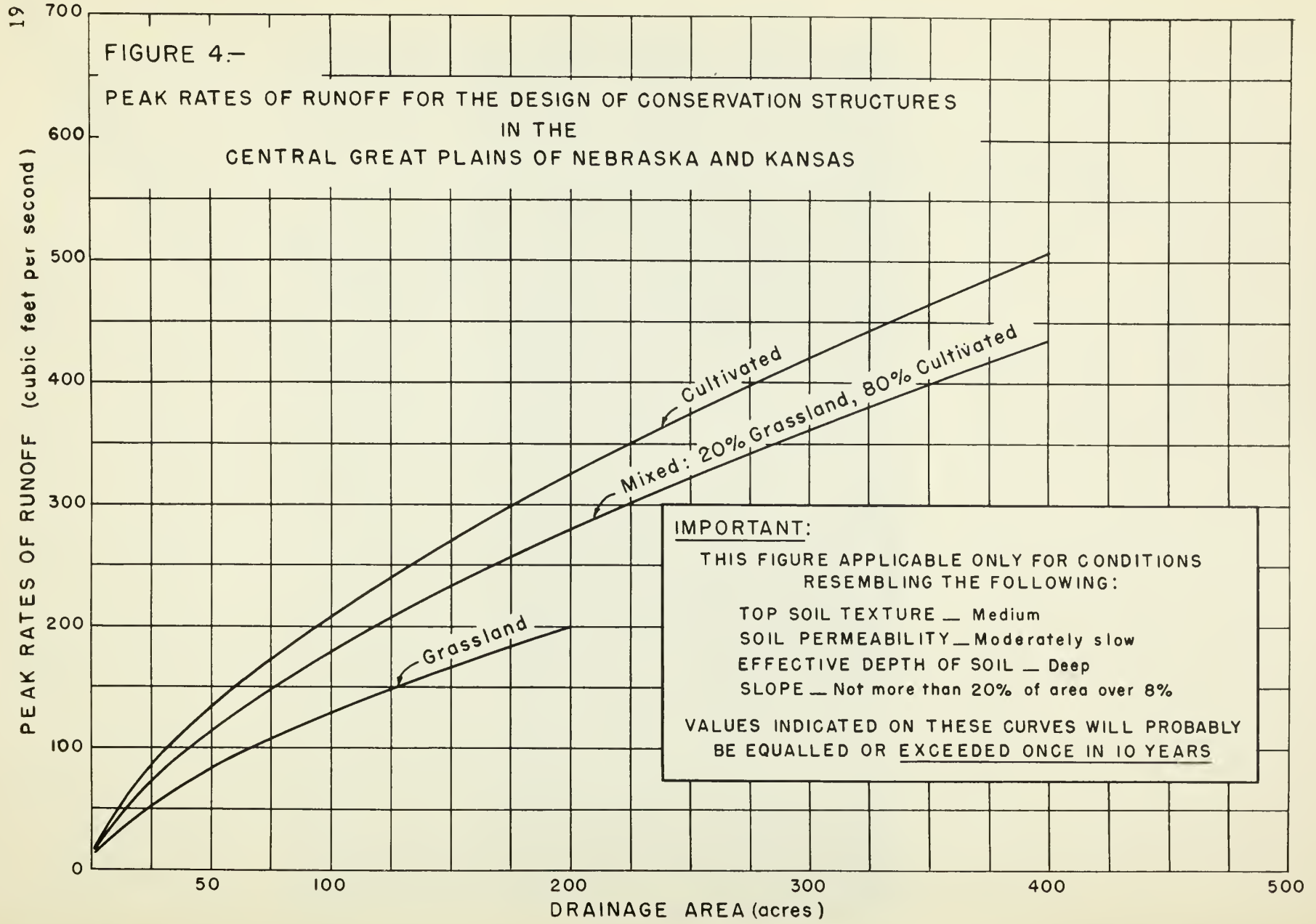


FIGURE 4.—
PEAK RATES OF RUNOFF FOR THE DESIGN OF CONSERVATION STRUCTURES
IN THE
CENTRAL GREAT PLAINS OF NEBRASKA AND KANSAS
PEAK RATES OF RUNOFF (cubic feet per second)
0
100
200
300
400
500
600
700
DRAINAGE AREA (acres)
50
100
200
300
400
500
Cultivated
Mixed: 20% Grassland, 80% Cultivated
Grassland
IMPORTANT:
THIS FIGURE APPLICABLE ONLY FOR CONDITIONS RESEMBLING THE FOLLOWING:
TOP SOIL TEXTURE — Medium
SOIL PERMEABILITY — Moderately slow
EFFECTIVE DEPTH OF SOIL — Deep
SLOPE — Not more than 20% of area over 8%
VALUES INDICATED ON THESE CURVES WILL PROBABLY BE EQUALLED OR EXCEEDED ONCE IN 10 YEARS

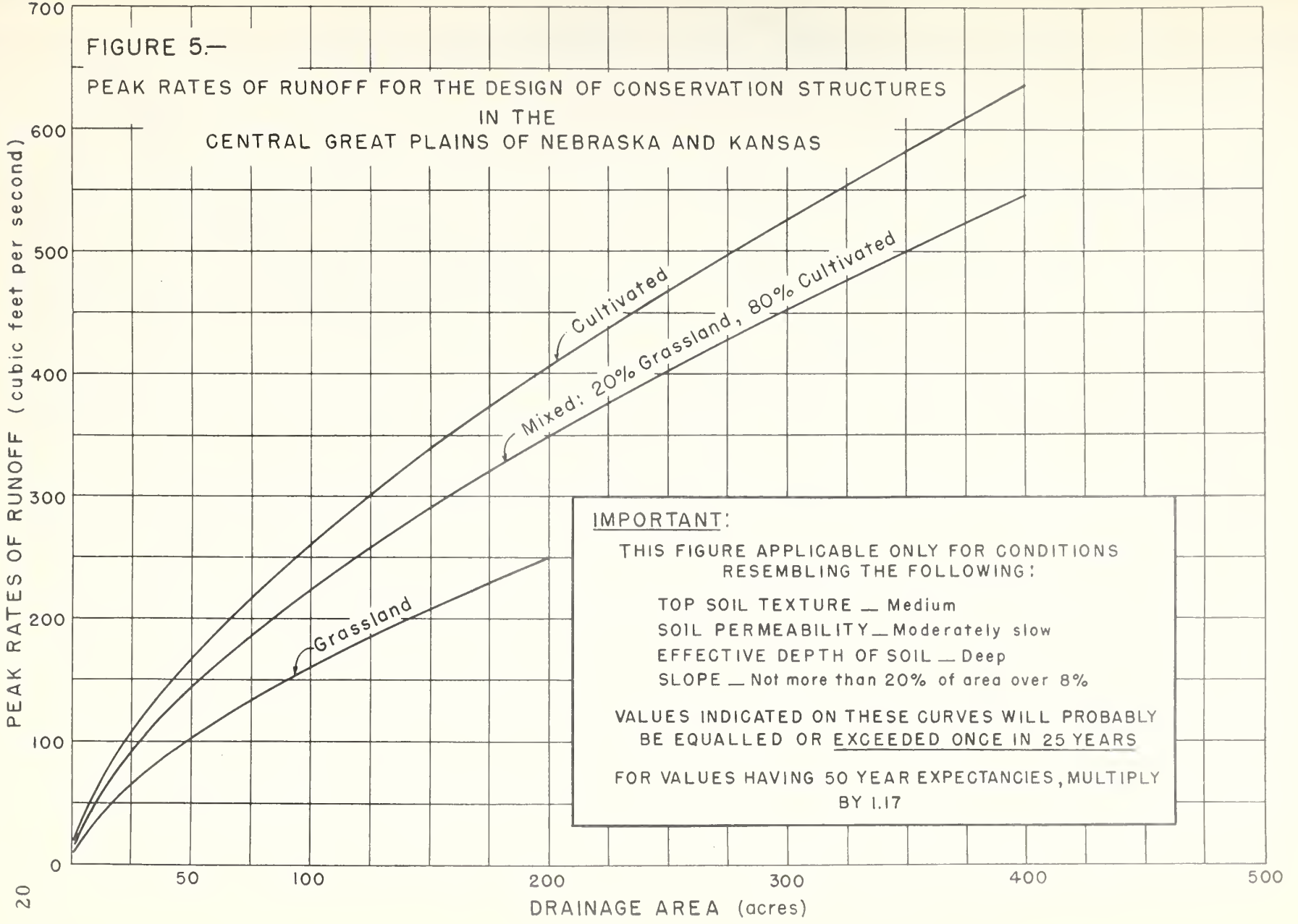


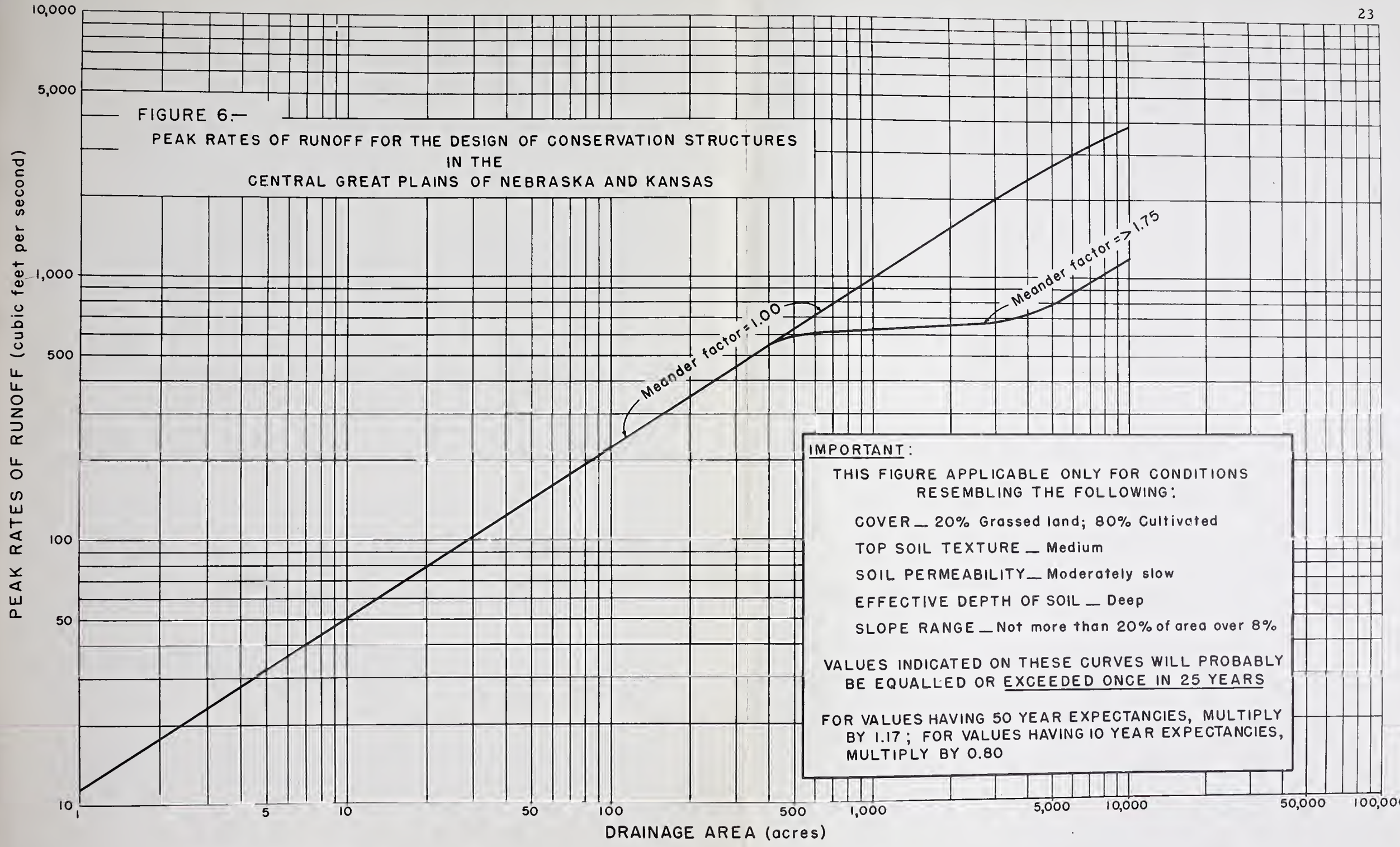
FIGURE 5.—
PEAK RATES OF RUNOFF FOR THE DESIGN OF CONSERVATION STRUCTURES IN THE CENTRAL GREAT PLAINS OF NEBRASKA AND KANSAS
PEAK RATES OF RUNOFF (cubic feet per second)
700
600
500
400
300
200
100
0
Cultivated
Mixed: 20% Grassland, 80% Cultivated
Grassland
IMPORTANT:
THIS FIGURE APPLICABLE ONLY FOR CONDITIONS RESEMBLING THE FOLLOWING:
TOP SOIL TEXTURE — Medium
SOIL PERMEABILITY — Moderately slow
EFFECTIVE DEPTH OF SOIL — Deep
SLOPE — Not more than 20% of area over 8%
VALUES INDICATED ON THESE CURVES WILL PROBABLY BE EQUALLED OR EXCEEDED ONCE IN 25 YEARS
FOR VALUES HAVING 50 YEAR EXPECTANCIES, MULTIPLY BY 1.17
50
100
200
300
400
500
DRAINAGE AREA (acres)

PLATE 7.--Meandering channel in vicinity of gaging station W-11.

PLATE 8.--View showing meandering flow above gaging station W-8, approximately 300 cubic feet per second, June 5, 1942.

FIGURE 6.—

PEAK RATES OF RUNOFF FOR THE DESIGN OF CONSERVATION STRUCTURES
IN THE
CENTRAL GREAT PLAINS OF NEBRASKA AND KANSAS



IMPORTANT:

THIS FIGURE APPLICABLE ONLY FOR CONDITIONS RESEMBLING THE FOLLOWING:

COVER — 20% Grassed land; 80% Cultivated

TOP SOIL TEXTURE — Medium

SOIL PERMEABILITY — Moderately slow

EFFECTIVE DEPTH OF SOIL — Deep

SLOPE RANGE — Not more than 20% of area over 8%

VALUES INDICATED ON THESE CURVES WILL PROBABLY BE EQUALLED OR EXCEEDED ONCE IN 25 YEARS

FOR VALUES HAVING 50 YEAR EXPECTANCIES, MULTIPLY BY 1.17; FOR VALUES HAVING 10 YEAR EXPECTANCIES, MULTIPLY BY 0.80

SOIL CONSERVATION SERVICE, WASHINGTON, D.C., 1948

Example

Given: a 2,000-acre watershed with a meander factor of 1.50

To find: the peak rate to be expected once in 25 years

	Meander factor	Peak rate
Upper curve	1.00	1,550 c. f. s.
Given watershed	1.50	?
Lower curve	1.75	660 c. f. s.

Required peak rate = (25/75 x 890) + 660 = 297 + 660 = 957 c. f. s.

The design values recommended in this report are based primarily on probability studies made of the peak rates of runoff from the watersheds of the Central Great Plains Experimental Watershed for the 8-year period of record, 1939-46.[3/] Similar studies were also made of United States Geological Survey data on large drainage basins (500-7,000 square miles) within the area of application. Values derived from these latter studies were used to extend the peak rate of runoff versus watershed-area curves beyond the size range of the experimental watersheds (fig. 6, p. 23).

The reliability of a probability study of surface runoff depends largely upon whether or not the factors that affected the surface runoff during the period of record were representative of what might be expected over a long period of years.

Since physiographic features and land use change but little from year to year, these factors for the period of record were considered to be good samples of longer periods. Rainfall, however, besides being the source of most surface runoff is probably the most variable factor affecting that runoff. For this reason, three comparisons were made of the rainfall for the period of record with that obtained from long time United States Weather Bureau records.

Probability studies were made of the record amounts of rainfall for the 6-month period, April through September, and compared with similar studies based on a 43-year United States Weather Bureau record for Hastings, Nebr. For recurrence intervals of 2 to 50 years, the comparison showed the amounts obtained for the period of record to be equal to or slightly greater than those for the 43-year period.

The average number of excessive storms, both annual and for the 6-month period, April through September, during the period of record, was compared with Yarnell's 30-year averages and were found to differ by only 0.2.[4/]

Probability studies were made of record 15-, 30-, 60-, and 120-minute intensities and compared with similar studies based on a 27-year United States Weather Bureau record for Lincoln, Nebr. For recurrence intervals of 2 to 50 years, the comparison showed the intensities obtained for the period of record to be equal to or slightly greater than those for the 27-year period.

3/POTTER, W. D. Analytical Procedures for Determining the Effect of Land Use on Surface Runoff. Agr. Engin. 29: 64-73, illus. 1948

4/YARNELL, D. L. Rainfall Intensity-Frequency Data. U. S. Dept. Agr. Misc. Pub. 204, 67 pp., illus. 1935.

From the above comparisons it was concluded that the peak rates of runoff recorded during the period of record were a good sample of what might be expected over a long period. It is believed that the recommended values based on an analysis of these experimental data will be adequate for the economical design of conservation structures, provided their use is restricted to the areas to which they are applicable.

The physiographic and cultural features of the area of application shown in figure 1, page 2, are similar to those of the experimental watersheds. Within this general area of application, however, small local areas may be found where these features differ materially from those specified in table 4, page 18, and figures 4, 5, and 6, pages 19, 20, and 23. In such cases, the field technician must use his own judgment in deciding whether the noted differences would result in larger or smaller peak rates of runoff than those specified in the tables and graphs.

PART III

Factors Influencing Peak Rates of Runoff

Many factors such as intensity of rainfall, topography, drainage density, slope of watershed, vegetal cover, soil texture and depth, permeability and depth of subsoil and substratum, composition of soil, diurnal changes and temperatures, seasonal changes, cultivation and tillage, surface litter and mulch, and erosion have a bearing on peak rates of runoff.

Several experiments were started in 1939-42 at the Central Great Plains Experimental Watershed near Hastings, Nebr., to study the effect of land use and soil conservation practices on runoff from comparable areas.

Land-Use Practices

In 1939-41, runoff measuring devices were installed on 24 natural watersheds of approximately 4 acres each and a continuous runoff record has been obtained to date. Three of these watersheds are in native grass and the remaining 21 are under cultivation and farmed under field conditions, using a rotation of corn, oats, and wheat (pl. 9, p. 26). Table 5, page 27, lists the maximum yearly peak rates of runoff from watersheds planted to corn under 3 different land-use practices.

Pasture Studies

In 1939, runoff measuring devices were installed on eight pasture plots, 100 by 300 feet, containing 0.69 acre each. Four of these plots were contour furrowed (pl. 10, p. 29) and the remaining four were untreated. Two contour-furrowed plots and two untreated plots were heavily grazed, and two contour-furrowed and two untreated plots were lightly grazed. The maximum annual peak rates of runoff in inches per hour are given in table 6, page 30.

It is evident that the reductions in peak rates due to contour furrowing are highly significant. The reductions in peak rates due to light grazing are somewhat dependent upon the amount of cover. The effects of light grazing, however, are significant.

In 1946-47, it was decided to revise the working plan on pasture plots and include pasture renovation. An eccentric disk was used on two of the untreated plots, and additional furrows were inserted on two of the furrowed plots. In order to have duplicate plots in each treatment it was necessary that all plots be grazed alike, hence, all plots are now moderately grazed.

PLATE 9.--Contoured corn. Approximately 2.4 inches of rain fell on June 8-9, 1941. Picture taken 3 hours after rain.

TABLE 5.--*Maximum annual peak rates of runoff from watersheds with corn planted in straight rows, contoured, and subtilled*

Year	Straight row	Contoured	Subtilled
	In. per hr.	*In. per hr.*	*In. per hr.*
1939.....	1.11	0.36	----
	2.67	1.78	----
1940.....	1.07	.11	----
	1.55	.01	----
1941.....	3.94	.85	----
	2.01	.82	----
1942.....	3.64	2.88	6.47
	2.69	2.04	2.74
1943.....	4.41	2.47	1.83
	3.66	2.38	1.04
1944.....	3.44	2.58	.68
	3.50	1.66	2.17
1945	3.26	1.81	.88
	2.81	1.95	2.06
1946	4.99	.34	2,83
	6.59	5.63	2.36
1947	1.90	1.16	1.28
	1.85	.70	1.52
Average 1939-47	3.06	1.63	----
Average 1942-47	3.56	2.13	2.16

PLATE 10.--Furrowed pasture. Showing well sodded, lightly grazed pasture plot on June 9, 1941.

TABLE 6.--*Maximum annual peak rates of runoff from pasture plots under different treatments*

Year	Untreated plots		Contour-furrowed plots	
	Heavily grazed	Lightly grazed	Heavily grazed	Lightly grazed
	In. per. hr.	*In. per. hr.*	*In. per. hr.*	*In. per. hr.*
1940	0.73	0.58	0.04	0.02
	.30	.63	.02	.05
1941	1.15	.73	.06	.02
	1.07	1.29	.07	.06
1942	.80	.20	.07	.02
	.56	.34	.06	.05
1943	1.64	2.46	.12	.12
	1.23	.64	.10	.10
1944	.83	.18	.13	.04
	1.07	.40	.15	.07
1945	1.45	.36	.20	.11
	1.31	.86	.12	.15
Average	1.01	.72	.10	.07

Conservation Practices

To provide some guide as to the effectiveness of conservation practices in reducing runoff, a gaging station was established in 1939 on watershed W-3, which has a drainage area of 481 acres, and another in 1940 on watershed W-5, which has a drainage area of 411 acres. These two areas were selected because the various physiographic characteristics were comparable. In order to obtain a correlation in runoff between the two, data were collected from 1940 to 1946 so as to have a long enough record to determine the degree of variation that was ascribable to the slight differences in slope, soil, and ground cover of the two watersheds. It was found that the runoff from these two areas was similar both in peak rates and in total amount per acre.[5/] In May 1947, all the landowners and tenants in watershed W-5 signed Soil Conservation Service cooperative agreements to place their farms under a conservation program. The Webster County Work Unit is undertaking a conservation program for this area under the Hebron, Nebr., district office. The State and regional offices of the Soil Conservation Service have also provided technical assistance in this study and are cooperating with the Research office. Since the land use on W-3 is not expected to change materially, it is hoped that a future comparison of these two watersheds will show the effects of soil conservation practices on peak rates and total amounts of runoff.

5/POTTER, W. D. Analytical Procedures for Determining the Effect of Land Use on Surface Runoff. Agr. Engin. 29: 64-73, illus. 1948

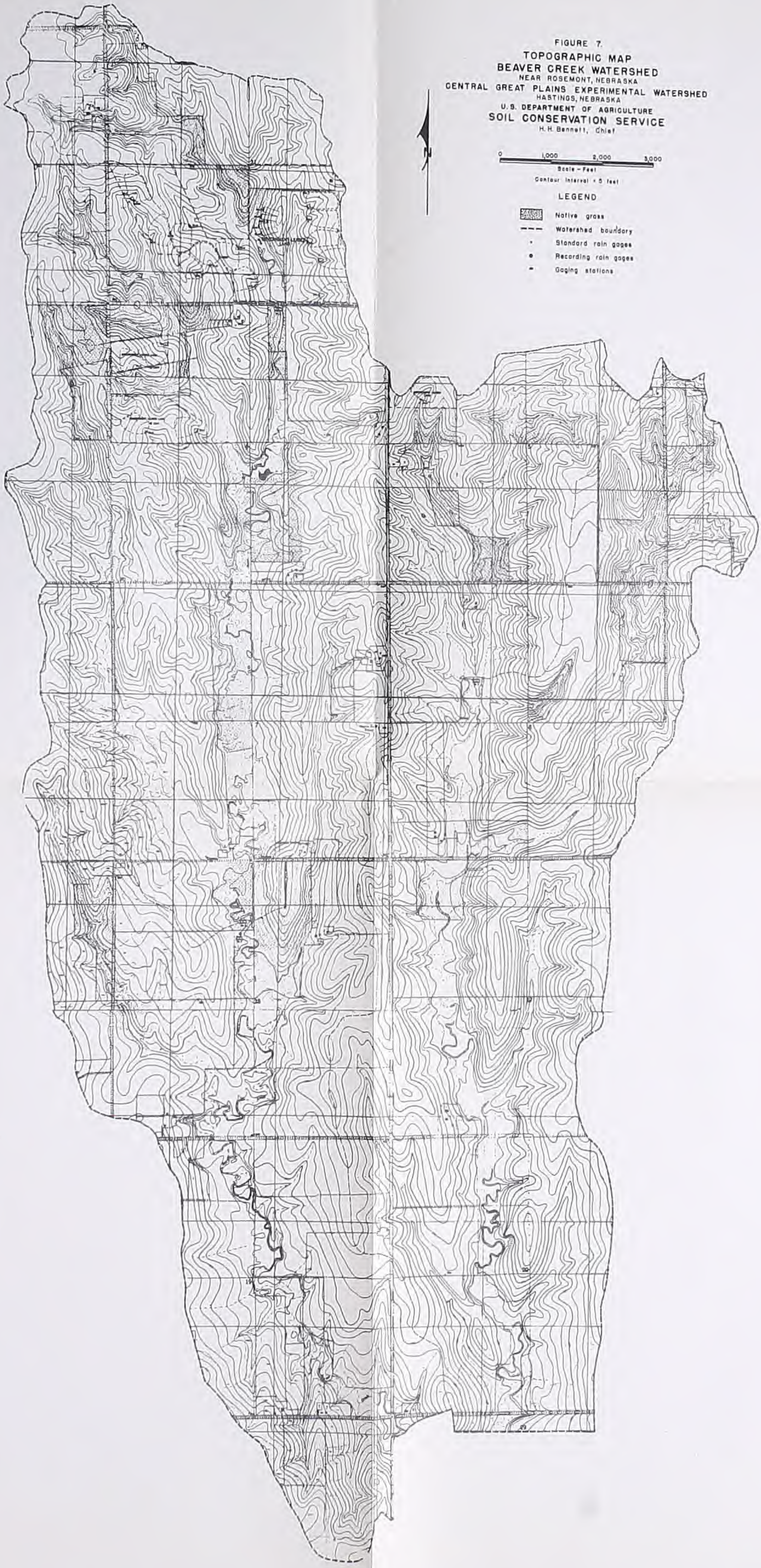
FIGURE 7.

TOPOGRAPHIC MAP
BEAVER CREEK WATERSHED
NEAR ROSEMONT, NEBRASKA
CENTRAL GREAT PLAINS EXPERIMENTAL WATERSHED
HASTINGS, NEBRASKA
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H.H. Bennett, Chief

N

0 1,000 2,000 3,000
Scale – Feet

Contour interval = 5 feet

LEGEND

- Native grass
- Watershed boundary
- Standard rain gages
- Recording rain gages
- Gaging stations